Explanation of Communication Protocol for AI Series Multi-channel Instruments

（V9.2）

Multiple-channel instruments above version V9. X support two communication protocols, AIBUS and MODBUS. AIBUS is independently developed by our company and can achieve comprehensive functions through simple commands. While writing parameters, it can also complete the reading function. Therefore, when writing parameters, it will not break the reading cycle time and allows up to 80 instruments to be connected on one RS485 communication interface. The MODBUS protocol has wider compatibility, and instruments above V9. X use the MODBUS protocol to read up to 20 words of data at a time, greatly improving communication efficiency compared to previous versions of our company. At a baud rate of 9600, the average time for the upper computer of the latest AI series instruments to access a V9. X version instrument is only about 20mS; When data transmission time is not considered, the maximum delay time after receiving instructions from the upper computer is only 10mS, and the average delay time is only 2-3mS, which is much faster than previous versions, making it easy to build large-scale process control systems. All the latest AI instruments of V9. X versions allow the upper computer to write more than 2 billion times, ensuring that internal memory is not damaged due to frequent writing by the upper computer. The upper computer can be used to form a complex adjustment system for the instruments. The AI series instruments can use PCs, touch screens, and PLCs as upper computers, and there are abundant configuration software resources available on the market. Windows is widely used in upper computer software based on PC, which is not only intuitive and convenient to operate, but also powerful in functionality. The latest applications of industrial tablets and touch screens make industrial automation easy to use, rich in features, and cost-effective. This makes the price of the measurement and control system (combined with instruments and upper computer) much lower than traditional DCS systems, and its distributed structure also has high reliability. Except for some newly launched models, the communication protocol of V9.XX version is fully compatible with that of V7.XX version while improving performance and functionality. The customer's original upper computer software can be used directly without modification.

一、 Interface specifications

The AI series instruments use asynchronous serial communication interfaces, and the interface level complies with the RS232C or RS485 standards. The data format is 1 start bit, 8 bit data, no checksum, 1 or 2 stop bits. The baud rate for communication transmission data can be adjusted from 4800 to 19200 bps, usually 9600 bps. When a faster refresh rate is needed, 19200 can also be tried. When the communication distance is long or cannot be interrupted reliably, 4800 bps is optional.

The communication distance of RS485 communication interface can reach over 1KM (some have reached 3-4KM), and multiple AI instruments can communicate with computers with just two wires. RS232/RS485 or USB/RS485 converters can be used by ordinary computers to convert RS232 or USB slots on the computer into RS485 communication slots. Our company's RS232/RS485 and USB/RS485 converters have a small size, can adapt to any software without initialization, do not require external power supply, and have certain lightning resistance. The RS485 communication interface can connect up to 32 instruments on a single communication line. When more instruments need to be connected, repeaters are needed, or communication interfaces with chips such as 1/2 or 1/4 load are used to increase the number of connected instruments. The current AI instrument communication interface uses low load chips and has certain lightning and anti-static functions, which can connect about 60 channels of instruments without the need for repeaters.

Optoelectronic isolation technology is adopted by the RS232 and RS485 communication interfaces of AI instruments to isolate the communication interface from other parts of the instrument line. When one instrument on the communication line is damaged or malfunctioning, it will not affect other instruments. Similarly, when communication is partially damaged or the host malfunctions, the instrument can still measure and control normally, and can be operated through the keyboard with high reliability. When there are products from other companies using master-slave communication on the same network, such as PLCs, frequency converters, etc., it should be noted that to ensure the normal operation of other company products, different communication lines should be used separately, or MODBUS protocol should be used, instead of mixing AI instruments with other products on the same RS485 communication bus.

The H term of the AF parameter is used by multiple instruments to switch between two protocols. H=0, AIBUS, occupying multiple addresses, and H=1, MODBUS-RTU, occupying only one address; namely when AF>=128, it is MODBUS, otherwise it is AIBUS. AF is a multifunctional set parameter, please refer to the manual for specific settings.

二、 Explanation of AIBUS protocol

The hexadecimal data format is adopted to represent various instruction codes and data. There are two communication instructions for AIBUS, namely reading and writing. The sending byte length of the instruction is 8 bytes, while the receiving byte length is 10 bytes. This not only makes it easy to write software for the upper computer, but also enables complete operation of the instrument. The instructions must be sent continuously. If the byte length is incorrect, the instrument will not respond.

Instrument address: The AIBUS protocol addresses range from 0 to 80, and a maximum of 81 AI instruments can be connected on a communication line. The communication address is determined by the parameter Addr. Two duplicate values between 128 and 2008 (80H~D0H in hexadecimal) are used to represent the address code. Since consecutive numbers between 128 and 2008 usually do not appear, data and address do not conflict due to duplication. The AI instrument communication protocol stipulates that the address instruction is two identical bytes with a value of (instrument address+80H). For example, if the instrument parameter Addr=10 (hexadecimal number is 0AH, 0A+80H=8AH), then the address command of the instrument is:

8AH 8AH

Parameter Address: The parameter address code of an 8-bit binary number (one byte) is used to represent the parameter name to be read/written in the instruction. The meanings of various parameters are shown in the table below.

Verification code: The 16 bit sum verification method is adopted, and the calculation method for the verification code of the read instruction is:

parameter code to be read * 256+82 (52H)+Addr

The calculation method for the checksum of writing instructions is the remainder calculated by performing a 16 bit binary addition using the following formula (overflow part not handled):

Parameter code to be written * 256+67 (43H)+parameter value to be written+Addr

Return data: Whether reading or writing, the instrument returns 10 bytes of data, with PV, SV, and read parameter values each accounting for 2 bytes, representing a 16 bit binary signed complement integer. The low byte comes first, the high byte comes last, and integers cannot represent decimal points. Users are required to process them on the upper computer; MV occupies one byte, in 8-bit signed binary format, with a numerical range of -110~+110. The status bit occupies one byte, and the checksum occupies two bytes, totaling 10 bytes. The checksum is PV+SV+(alarm status * 256+MV)+parameter value+Addr, which is the remainder obtained by adding a 16 bit integer. Overflow is ignored.

The specific interaction commands are as follows:

When using AIBUS, multiple instruments occupy multiple addresses, occupying the same number of channels as Cn. For example, if 706M only uses 5 channels, setting Cn=5 and addr=1 will occupy addresses 1-5, and setting the station number of the next instrument to 6. Send read commands to the corresponding address when reading and writing PV or

parameters of the corresponding channel.

Reading:

Code of LSB	Code of MSB	instruction	code	Value of LSB	Value of MSB	Checksum of LSB	Checksum of MSB
80H+ Instrument address	80H+ Instrument address	52H	Refer to the parameter code table	00H(fixed)	00H(fixed)	Refer to Note 1	

Note 1: Checksum= parameter code of Reading* 256 (100H)+82 (52H)+Instrument address

The command to read the upper limit alarm value of address 1 is as follows:

Code of LSB	Code of MSB	instruction	code	Value of LSB	Value of MSB	Checksum of LSB	Checksum of MSB
81H	81H	52H	01H	00H	00H	53H	01H

Checksum=1(01H)*256(100H)+1(01H)+82(52H) = 339(153H), because the low byte (LSB) comes first and the high byte (MSB) comes last, it is listed as 53H and 01H in the table above.

Writing:

Code of LSB	Code of MSB	instruction	code	Value of LSB	Value of MSB	Checksum of LSB	Checksum of MSB
80H+ Instrument address	80H+ Instrument address	43H	Refer to the parameter code table	Refer to Note 1		Refer to Note 2	

Note 1: The data that needs to be written into the instrument should have low bytes before and high bytes after.

Note 2: Checksum=(parameter code of Writing*256 (100H)+67 (43H)+instrument address+write value)&FFFFH to obtain remainder

The command to write the upper limit alarm value of address 1 is 100, shown as follows:

Code of LSB	Code of MSB	instruction	code	Value of LSB	Value of MSB	Checksum of LSB	Checksum of MSB
81H	81H	43H	01H	E8H	03H	2CH	05H

Checksum=1(01H)*256(100H)+1(01H)+1000(3E8H)+67(43H)= 1324(52H), because the low byte (LSB) comes first and the high byte (MSB) comes last, it is listed as 2CH and 05H in the table above.

Return data: Whether reading or writing, the instrument returns 10 bytes of data.

PV of LSB	PV of MSB	SV of LSB	SV of MSB	Output value Of MV	Status Byte	parameter values LSB	parameter values MSB	Checksum of LSB	Checksum of MSB
Note 1								Note 2	

Note 1: PV=(PV of MSB*256)+PV of LSB

The parsing method for SV and parameter values of reading or writing is the same

Note 2: Checksum=(PV+SV+status byte*256+output value of MV+parameter value of reading or writing+instrument address)&FFFFFFH is the remainder obtained. When communication data is interfered with, the checksum in the return value can be compared with the calculated checksum during collection. If the two are the same, the data is normal.

Otherwise, it may be abnormal due to interference.

It is worth noting that the inspection instrument does not have SV, and the SV in the return value actually corresponds to the PV of the next path. The MV is used to correspond to the output status, with bits 0 to 6 indicating OP1, OP2, AL1, AL2, AU1, AU2, MIO, and 1 indicating action.

Assuming that channel 1 of the instrument shows a PV of 100.0 and channel 2 shows a value of 200.0, with no input or output from alarm logic, the command returned for reading or writing HIAL as 0.0 is as follows:

PV of LSB	PV of MSB	SV of LSB	SV of MSB	Output value Of MV	Status Byte	parameter values LSB	parameter values MSB	Checksum of LSB	Checksum of MSB
E8H	03H	D0H	07H	00H	60H	00H	00H	B9H	6BH

The status byte represents the status of instrument alarms and alarm relays, and its meaning is as follows (bit 7 is fixed to 0):

Status Byte	Description
Bit 0	HIAL 0: No alarm 1: Alarm
Bit 1	LoAL 0: No alarm 1: Alarm
Bit 2	dHAL 0: No alarm 1: Alarm
Bit 3	dLAL 0: No alarm 1: Alarm
Bit 4	orAL 0: No alarm 1: Alarm
Bit 5	AL1 status, 0 action
Bit 6	AL2 status, 0 action

三、 Explanation of MODBUS-RTU protocol

The AI series instruments support two commands under the MODBUS protocol: 03H (read parameters and data) and 06H (write individual parameters). It can communicate with other MODBUS devices, and to ensure speed, the AI instrument adopts RTU (binary) mode. The baud rate should be set to 9600 or 19200, with 1 or 2 stop bits, no parity check bits, and the instrument address range is 0-80. In MODBUS mode, the multiplexer only occupies one address.

The 03H instruction can read 1-20 data at a time, with each data being 2 bytes. For example, the instruction to read 2 data is as follows:

Instrument address	Reading instructions (function code)	Read address of parameter code	Read data length	Checksum
XXH	03H	00H XXH	00H 02H	CRC

The format of the instruction for writing 06H, for example, if the HIAL value is 100.0 (parameter dPt=1), then the instruction to be sent is:

Instrument address	Reading instructions (function code)	Read address of parameter code	Read data length	Checksum
XXH	06H	00H 01H	03H E8H	CRC

The format of returned data follows the standard MODBUS protocol, and the user's configuration software can usually handle it on its own. Writing instructions only return the parameter values written by themselves, and do not support returning PV or other information. Due to the limitations of the MODBUS protocol, when a write instruction cannot return PV or other information, it will result in the written PV being unable to be refreshed. The method of writing once and then alternately reading again is used to continuously write parameters to avoid the inability to refresh PV and other information in a timely manner during continuous writing. In addition, if a bug in the program causes a write instruction to be mistakenly called, it may lead to incorrect parameter writing to the instrument. Therefore, it is advisable to minimize the use of write instructions in the program to avoid abnormal operation of the instrument.

Our company's Modbus AIBUS communication relay control and protocol converter can be used to read large amounts of data more efficiently. For detailed information, please refer to the relevant product users' manual. The 7xx8 series does not support the S6 module.

四、Correspondence to communication registers (range of AIBUS register up to 1CH, followed by MODBUS specific registers)

10 base code	16 base code	MODBUS register	Patrol inspection instrument AI-702M/704M/706M	Multi-channel PID controller AI-7028/7048	Multi-channel PID controller AI-7xx8 (including 7668, 7648 and their sub models 7568, 7548, etc.)
0	0	40001		SP1	SP1
1	1	40002	HAL1	HAL1	HAL1
2	2	40003	LAL1	LAL1	LAL1
3	3	40004			
4	4	40005			
5	5	40006	HYS1	HYS1	HYS
6	6	40007		AT1	AT1
7	7	40008		P1	P1
8	8	40009		I1	I1
9	9	40010		D1	D1
10	A	40011	Cn	CTI	CTI
11	B	40012	INP1	INP1	INP
12	C	40013	dPt1	dPt1	dPt
13	D	40014	SCL1	SCL1	
14	E	40015	SCH1	SCH1	
15	F	40016	AOP1	AOP1	AOP1
16	10	40017	ScB1	ScB1	ScB1
17	11	40018	OPn		OP1
18	12	40019	oPL		OPL1
19	13	40020	oPH	OPH1	OPH1
20	14	40021	AF	AF	AF

21	15	40022	Characteristic code	Characteristic characters	Characteristic characters
22	16	40023	Instrument address (read/write)	Instrument address (read/write)	Instrument address (read/write)
23	17	40024	FIL1	FIL1	FIL1
24	18	40025	nonc	nonc	nonc
25	19	40026	4 low digits of machine number	4 low digits of machine number	4 low digits of machine number
26	1A	40027		Cn	Cn
27	1B	40028	Cno	Cno	Cno
28	1C	40029		AF2	AF2
29	1D	40030			
30	1E	40031			
31	1F	40032			
32	20	40033		SP1	SP1
33	21	40034	HAL1	HAL1	HAL1
34	22	40035	LAL1	LAL1	LAL1
35	23	40036	AOP1	AOP1	AOP1
36	24	40037	HYS1	HYS1	
37	25	40038	INP1	INP1	OPL1
38	26	40039	dPt1	dPt1	OP1
39	27	40040	SCL1	SCL1	
40	28	40041	SCH1	SCH1	
41	29	40042	ScB1	ScB1	ScB1
42	2A	40043	FIL1	FIL1	FIL1
43	2B	40044		At1	At1
44	2C	40045		P1	P1
45	2D	40046		I1	I1
46	2E	40047		D1	D1
47	2F	40048		OPH1	OPH1
48	30	40049		SP2	SP2
49	31	40050	HAL2	HAL2	HAL2
50	32	40051	LAL2	LAL2	LAL2
51	33	40052	AOP2	AOP2	AOP2
52	34	40053	HYS2	HYS2	
53	35	40054	INP2	INP2	OPL2
54	36	40055	dPt2	dPt2	OP2
55	37	40056	SCL2	SCL2	
56	38	40057	SCH2	SCH2	
57	39	40058	ScB2	ScB2	ScB2
58	3A	40059	FIL2	FIL2	FIL2
59	3B	40060		At2	At2
60	3C	40061		P2	P2
61	3D	40062		I2	I2

62	3E	40063		d2	d2
63	3F	40064		OPH2	OPH2
64	40	40065		SP3	SP3
65	41	40066	HAL3	HAL3	HAL3
66	42	40067	LAL3	LAL3	LAL3
67	43	40068	AOP3	AOP3	AOP3
68	44	40069	HYS3	HYS3	
69	45	40070	INP3	INP3	OPL3
70	46	40071	dPt3	dPt3	OP3
71	47	40072	SCL3	SCL3	
72	48	40073	SCH3	SCH3	
73	49	40074	ScB3	ScB3	ScB3
74	4A	40075	FIL3	FIL3	FIL3
75	4B	40076		At3	At3
76	4C	40077		P3	P3
77	4D	40078		I3	I3
78	4E	40079		d3	d3
79	4F	40080		OPH3	OPH3
80	50	40081		SP4	SP4
81	51	40082	HAL4	HAL4	HAL4
82	52	40083	LAL4	LAL4	LAL4
83	53	40084	AOP4	AOP4	AOP4
84	54	40085	HYS4	HYS4	
85	55	40086	INP4	INP4	OPL4
86	56	40087	dPt4	dPt4	OP4
87	57	40088	SCL4	SCL4	
88	58	40089	SCH4	SCH4	
89	59	40090	ScB4	ScB4	ScB4
90	5A	40091	FIL4	FIL4	FIL4
91	5B	40092		At4	At4
92	5C	40093		P4	P4
93	5D	40094		I4	I4
94	5E	40095		d4	d4
95	5F	40096		OPH4	OPH4
96	60	40097			SP5
97	61	40098	HAL5		HAL5
98	62	40099	LAL5		LAL5
99	63	40100	AOP5		AOP5
100	64	40101	HYS5		
101	65	40102	INP5		OPL5
102	66	40103	dPt5		OP5
103	67	40104	SCL5		
104	68	40105	SCH5		

105	69	40106	ScB5		ScB5
106	6A	40107	FIL5		FIL5
107	6B	40108			At5
108	6C	40109			P5
109	6D	40110			I5
110	6E	40111			d5
111	6F	40112			OPH5
112	70	40113			SP6
113	71	40114	HAL6		HAL6
114	72	40115	LAL6		LAL6
115	73	40116	AOP6		AOP6
116	74	40117	HYS6		
117	75	40118	INP6		OPL6
118	76	40119	dPt6		OP6
119	77	40120	SCL6		
120	78	40121	SCH6		
121	79	40122	ScB6		ScB6
122	7A	40123	FIL6		FIL6
123	7B	40124			At6
124	7C	40125			P6
125	7D	40126			I6
126	7E	40127			d6
127	7F	40128			OPH6
128	80	40129	PV1	PV1	PV1
129	81	40130	PV2	PV2	PV2
130	82	40131	PV3	PV3	PV3
131	83	40132	PV4	PV4	PV4
132	84	40133	PV5		PV5
133	85	40134	PV6		PV6
134	86	40135			
135	87	40136			
136	88	40137	Alarm status	Alarm status	Alarm status
137	89	40138	Output status and ORAL	Output status and ORAL	Output status and ORAL
138	8A	40139		MV1	MV1
139	8B	40140		MV2	MV2
140	8C	40141		MV3	MV3
141	8D	40142		MV4	MV4
142	8E	40143			MV5
143	8F	40144			MV6

五、Introduction to Some Special Parameters

Name	Description
AT1~6	0: PID normal operation status 1: enable self-tuning 5: position adjustment operation status 10: stop status 20: manual operation status (new function added in 7xx8V9.21 version manually)
Alarm status	Address 40137, specialized alarm status bit judgment for modbus mode, bits 0~5 correspond to whether the upper limit alarm HAL.1~6 meets the alarm condition, and bits 8~13 correspond to whether the lower limit alarm LAL1~6 meets the alarm condition.
Output status and ORAL	Bits 0~7 correspond to OP1, OP2, AL1, AL2, OP3, OP4, OP5, OP6, and bits 8~13 represent ORAL1~ORAL6 over range bit judgment
nonc	Range 0-127, numbers beyond the range cannot be written. Bitwise correspondence, starting from bit 0, corresponds to nonc of OP1, OP2, AL1, AL2, AU1, AU2, and MIO. The 7048 and 7xx8 series can only be defined with nonc for AL1 and AL2 outputs.

The specific meanings of other parameters can be found in the manual.

六、Explanation

The master-slave multi machine communication structure is adopted, where each instruction is sent to the instrument and the instrument returns one data. When writing upper computer software, the instrument should respond to each valid command within 0-10mS (note: does not include data transmission time, which should be calculated based on different baud rates and data lengths). The upper computer must also wait for the instrument to return data before issuing new commands, otherwise it will cause errors. If the instrument still does not respond after exceeding the maximum response time, it may be due to invalid instructions, invalid instrument or parameter addresses, communication line faults, instrument not turning on, communication address mismatch, etc. At this time, the upper computer should resend instructions or skip changing the address of the instrument.

To improve efficiency, all values transmitted by the instrument are 16 bit binary complement integers, for example, the data transmitted at HIAL=100.0 ℃ is an integer 1000. The upper computer must convert integers into actual data with decimal points according to certain rules. That is, after the upper computer is started, the linear input should first read the parameter dPt (0CH) to obtain the decimal point position of the measurement signal. The sensor input type is table lookup method, with fixed decimal points, such as INP=0~9, 19~21, fixed to 1 decimal point, INP=22 fixed to 2 decimal points.

If the reading parameter code is outside the table (invalid parameter code or backup parameter code), the parameter value returned by the instrument is 32767. Since the maximum parameter setting range of AI series instruments is 32000, 32767 can be used as a symbol for reading incorrect parameter codes and processed in the upper computer program;

If the parameter code is written outside the table, or if the instrument model does not have this parameter, the instrument will not report an error, but will not execute the write and return the parameter value of 32767. If the written value exceeds the internal numerical range of the instrument, such as the set output value exceeding the system's allowed output upper limit value, the instrument will write the upper limit value and return the upper limit value.

15H is the characteristic character of the instrument model. Different models of instruments have different numbers, and the upper computer can be used to distinguish instrument models. Different models of upper computers perform different mode processing on their transmitted data. The table of instrument models and characteristic characters is as follows:

Model	characteristic character
AI-702M	770
AI-704M	772
AI-706M	774
AI-7x68	7668
AI-7x48	7648
AI-7028	7028
AI-7048	7048

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